Monitoring of Stresses in Planetary Bodies by Monitoring Infrared Emission

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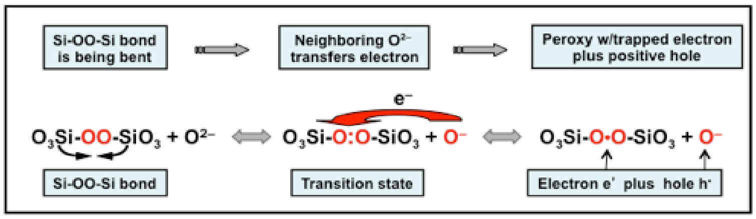
Earth is replete with tectonic stresses that wax and wane, but other solar system solid bodies are also active as indicated by the recent report of a marsquake [1]. Wouldn't it be great, if we could detect stresses on the moon and on Mars remotely from orbit or from Earth?

All rocks in solar system solid bodies contain peroxy defects in the matrix of their minerals: pairs of oxygen anions that have converted from the 2– valence state to the 1– valence state, typically $O_3Si\text{-}O{:}O\text{-}SiO_3$, where the two dots represent the two defect electrons or holes [2,3].



Stresses cause peroxy bonds to break, releasing holes $h^\bullet$, that flow out of the stressed rocks into the surrounding unstressed rocks, traveling fast (up to ~100 m/s) and far (many tens of km).

Figure 1a illustrates that, when $h^\bullet$ arrive at the surface, they recombine, returning to the peroxy state and releasing ~2.1 eV. In the process, the new peroxy bonds are vibrationally excited, emitting IR photons corresponding to the downward transitions within the vibrational manifold.

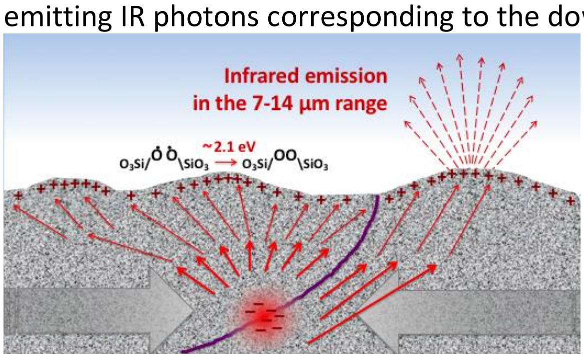


Figure 1a: Stress activation of h• charge carriers deep below that recombine and emit characteristic IR photons from the surface.

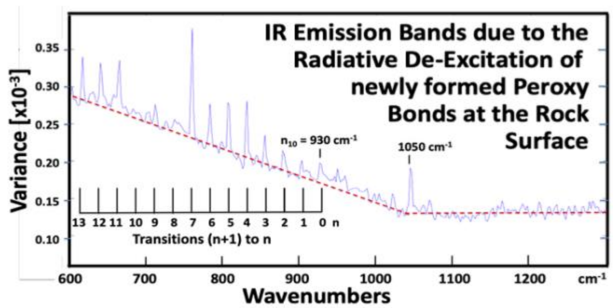


Figure 1b: Variance of the IR radiation emitted during stressing a block of gabbro at its far end. Sharp lines due to the vibrational de-excitation of peroxy bonds.

Figure 1a indicates how to remotely detect stresses building up deep below the surface of a planetary body. The red area marks a volume, where peroxy defects become stress-activated, releasing highly mobile $h^\bullet$ charge carriers that spread through the rock column. At the surface, the $h^\bullet$ accumulate at topographic highs and recombine, forming peroxy bonds again. About ~2.1 eV are released, leading to vibrationally highly excited oxygen pairs. **Figure 2b** shows that, during de-excitation, IR photons can be recognized corresponding to the downward transitions in the O–O vibrational manifold. At the same time, due to secondary and tertiary excitations, the long wavelength background increases in a way corresponding to pink noise.

1 Wikipedia. https://en.wikipedia.org/wiki/Quake_(natural_phenomenon)#Marsquake. (2019).
2 Scoville, J., Sornette, J. & Freund, F. T. Paradox of peroxy defects and positive holes in rocks Part II: Outflow of electric currents from stressed rocks. *Journal Asian Earth Sciences* **114, Part 2**, 338-351, (2015).
3 Freund, F. T. & Freund, M. M. Paradox of Peroxy Defects and Positive Holes in Rocks Part I: Effect of Temperature. *Journal of Asian Earth Sciences* **2015**, 373-383, doi: 10.1016/j.jseaes.2015.04.047 (2015).